Comparison of Fuzzy Classifiers Based on Fuzzy Membership Functions : Applies to Satellite Landsat TM Image

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Abstract: The aim of this study is to compare the classification results for choosing the fuzzy membership function within fuzzy rules. There are various methods of extracting rules from training data in the process of fuzzy rules generation. Pattern distribution characteristics are considered to produce fuzzy rules. The accuracy of classification results are depended on not only considering the characteristics of fuzzy subspaces but also choosing the fuzzy membership functions.

This paper shows how to produce various type of fuzzy rules from the partitioning the pattern spaces and results of land cover classification in satellite remote sensing images by adopting various fuzzy membership functions. The experiments of this study is applied to Landsat TM image and the results of classification are compared by fuzzy membership functions.

1. INTRODUCTION

There are many methodologies to apply remote sensing image classification, such as fuzzy logic, neural network theory, etc. compared with the previous statistical procedures. For instance, neural network can accomplish efficiently the classification of the non-normal distributional category (which is hard to classify under pre-existing statistical method). Other recent researches attempt to improve the classificational category, utilizing the fuzzy membership function. Particularly, F. Wang's research regarding the application of the membership grade on the mixed pixel to reduce the loss of information is significant. This research paper will attempt the classification of the multi-spectral image through the fuzzy rule; then, the rule will be analyzed by adapting its membership grade.

Using the fuzzy set, fuzzy logic, fuzzy number, and such, the fuzzy theory can represents ambiguous and vague situations very well. The fuzzy theory is also acknowledged in pattern recognition fields as a versatile tool with many application. However, to apply the fuzzy theory in practical applications, the method of construction of the fuzzy rule must be determined. There are two approaches. The first approach employs human expert to define and to manipulate the fuzzy rule, and the other approach automatically generates the fuzzy rule through learning. To define fuzzy rule is not easy in the former case. Because the dimension of the pattern space such as a remote sensing image has multi-dimensional pattern space, and the category is variable. Therefore, in this case, the fuzzy rule generated by partitioning a given pattern space brings effective solution. But, as the existing method disregards the status of pattern space distribution, the generated fuzzy rule predicates on uniformal partition. Hence, the accuracy for generated rule is relatively low and the number of rules increases as well. However, with the careful consideration for the pattern space distribution, this paper proposes, for the satellite image classification, the partitioning method of the multi-dimensional spectral space. Subsequently, the membership grade is defined by the pattern distribution for the pertinent fuzzy rule generated for that pertinent subspace.

2. FUZZY CLASSIFIERS

From the pattern partitioning procedure, the fuzzy subspaces are generated and fuzzy rules are defined from each subspace. The method of generating the fuzzy rules are as follows:

If the fuzzy space divides into T number of subspaces, then the T numbers of the fuzzy rules are defined as follows:

Rule R_t : IF (x_1 is $A_1^{r_t}$ AND x_2 is $A_2^{r_t}$ AND ... AND x_n is $A_n^{r_t}$)
THEN $(x_1, x_2 \cdots, x_n)$ belong to C^{r_t}
WITH $CF = CF^{r_t}$

Each fuzzy partition is defined by the triangular or trapezoidal membership function. In triangular function, when the value of the membership grade is one, that point is the mean vector point for that particular subspace, and when the value of the membership grade is zero, the points are one-half longer than the length of the pattern coordinates on the subspace. In trapezoidal function, σ showing the standard deviation of the pattern distribution. The purposes are to extend the hard-partition problems of the subspace into the fuzzy space.

<Generation of Fuzzy If-then Rule>

Step 1-1. The triangular fuzzy membership function for the given subspace;

IF $x_i \leq b$ then

$$\mu_i(x_i) = MAX(0,(0.5x+0.5b-a)/(b-a))$$

else

$$\mu_i(x_i) = MAX(0,(0.5x+0.5b-c)/(b-c))$$

where, a $=\alpha_i^{\prime}$, c $=\beta_i^{\prime}$, b $=M_i^x$, i = 1,2,...,n

Step 1-2. The trapezoidal fuzzy membership function for the given subspace;

$$\begin{aligned} \mu_i(x_i) &= MAX(0,(x+\sigma-a)/\sigma) & x_i < a \\ &= 1 & a \le x_i \le b \\ &= MAX(0,(-x+\sigma+b) & x_i > b \end{aligned}$$

where, a $=\alpha_i^{\prime}$, b $=\beta_i^{\prime}$, i = 1, CF^{r_i} 2,...,n

Step 2. The certainty factor of the fuzzy if-then rule CF^{r_i} is calculated by the following equations.

$$TR = \sum_{p \in C_x} MIN\ \mu_j^1(x_{p1}), \mu_j^2(x_{p2}), \cdots, \mu_j^n(x_{pn})$$

$$TW = \sum_{p \notin C_x} MIN\ \mu_j^1(x_{p1}), \mu_j^2(x_{p2}), \cdots, \mu_j^n(x_{pn})$$

$$CF^{r_i} = \frac{TR}{TR+TW}$$

where, $j = 1, 2, \cdots, K$

Step 3. The consequence C^{r_i} becomes C_x .

<Class Decision Rule>

Images form the satellite remote sensing are classified from the membership degree of the fuzzy rule and confidence value which can be calculated from the certainty factor. The following shows the decision procedure to classify the mixel image.

1 Get the membership grade from every fuzzy rule which includes each pixel.

2 The membership grade of each band from the fuzzy rules depends on the membership function(triangular or trapezoid). The certainty factor is calculated by previous definition from this equation.

$$CF = \frac{TR}{TR+TW}$$

3 Get the minimum membership grade from applying fuzzy rules, and get the confidence value from multiplying CF value with the membership grade.

4 Finally, it is classified as one category because of the maximum confidence value.

3. EXPERIMENTS

The fuzzy classifiers are applied to one area in Seoul from the satellite Landsat TM image. To simplify the experiment, the bands with the most favorable classification characteristics were chosen. The selected bands were two, four, and seven. The four classification categories were forest, water, crop and urban areas. As the training data, three to five areas were chosen from each of the four classification categories and 25 pixels were selected from each of these areas.

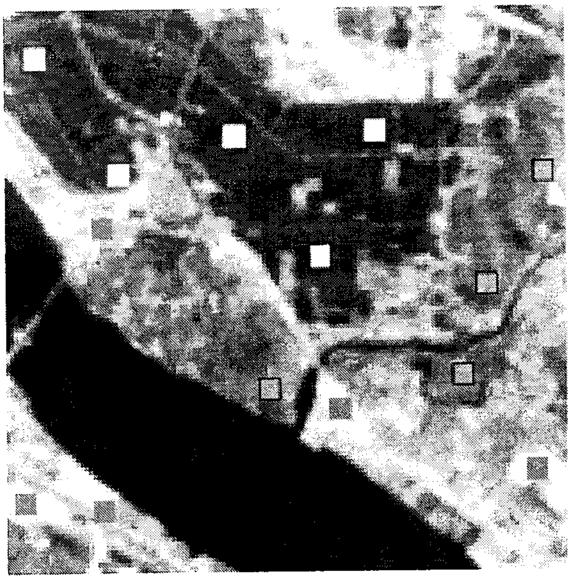
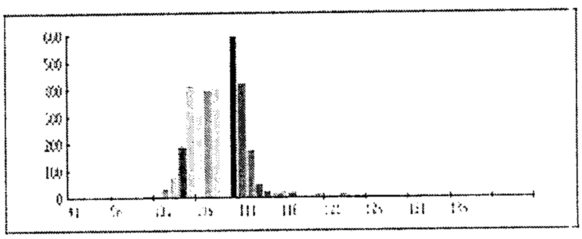
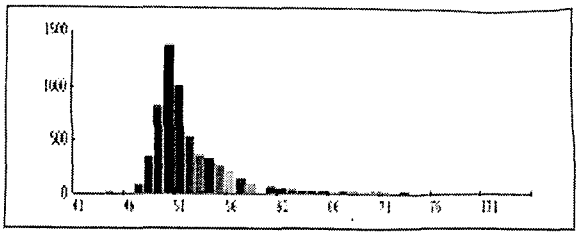


Fig. 1. Landsat TM image and training fields

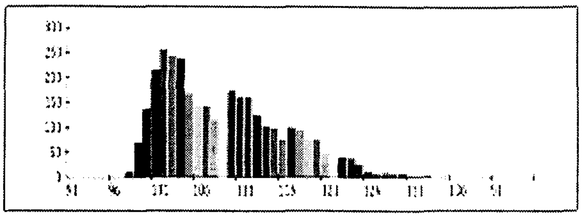
Fig. 1 shows the image of Landsat TM which includes their training fields. Table 1 and 2 show the classification results by the fuzzy classifiers. Fig. 2 shows histograms of category classes. Fig. 3 and 4 show the classification results graphs by typical triangular and trapezoidal membership functions.



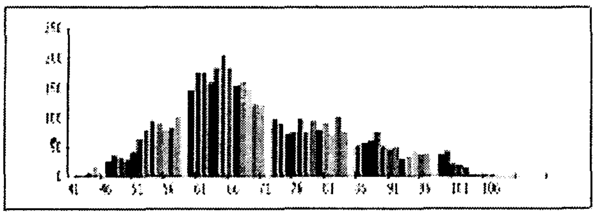
· Water (band-1 : 99<109<131)



· Crop (band-2 : 43<49<79)



· Forest (band-1 : 97<101<134)



· Urban (band-3 : 41<64<106)

Fig. 2. Histogram of category classes

Images form the satellite remote sensing are classified from the membership degree of the fuzzy rule and confidence value which can be calculated from the certainty factor. The following shows the decision procedure to classify the images.

Table 1. Classification results(triangular: 0.7)

	Pixel	Water	Crop	Forest	Urban	Accuracy(%)
Water	3894	3329	307	134	48	85.5
Crop	5851	0	4417	834	570	75.5
Forest	3380	32	251	2551	497	75.5
Urban	4740	17	990	1419	2243	47.3
Sum	17865					70.2

Table 2. Classification results(trapezoidal: 0.7)

	Pixel	Water	Crop	Forest	Urban	Accuracy(%)
Water	3894	3251	358	117	168	83.5
Crop	5851	0	3768	432	1651	64.4
Forest	3380	29	86	2037	1228	60.3
Urban	4740	13	296	4808	3951	83.4
Sum	17865					72.8

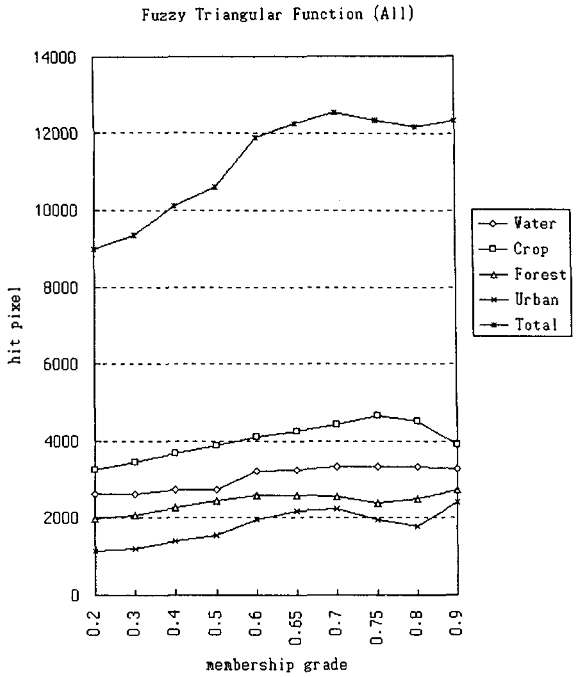


Fig. 3. Classification results graph(applies to fuzzy triangular membership function)

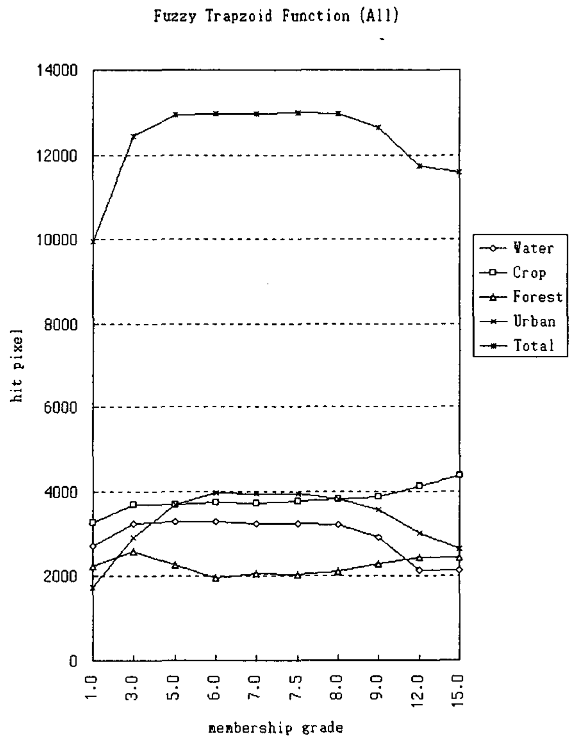


Fig. 4. Classification results graph(applies to fuzzy trapezoidal membership function)

4. CONCLUSION

Fuzzy rules for classification of remotely sensed image are represented. As the fuzzy classifier, compared with the previous statistical methods, considers the pattern distribution for the classification category and the unnecessary rules are reduced. In addition, the rules allow the membership grade for category grew larger. In this research, fuzzy triangular and trapezoidal functions are applied to the classification. The accuracy of the classification improves because the fuzzy rules are determined by considering the characteristics of the fuzzy subspaces. The classifiers are applied to 2, 4, 7 band of satellite Landsat TM and the best results show in fuzzy trapezoidal function by using 7.5σ.

Future research tasks are desirable to work on the real or aerial photo in details in order to analyze mixed components within one pixel. The results can be employed for the practical application.

References

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